


# The Predictive Value of Preoperative Measurements of Cochlear Nerve Diameters From MRT and Postoperative Speech Perception in Adult Patients With Cochlear Implant

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**Objective:** The current study aims to investigate whether objective measurements of the cochlear nerve (CN), derived from preoperative MRI images, correlate with postoperative speech perception in CI patients.

**Study Design:** Retrospective cohort study.

**Setting:** University Medical Center, tertiary academic referral center.

**Patients:** Patients undergoing a cochlear implant surgery including MED-EL (Synchrony 2, FLEX electrode series; MED-EL, Innsbruck, Austria) Cochlear (slim straight electrodes; Cochlear Ltd., Sydney, Australia), Advanced Bionics (HiRes Ultra 3D CI, HiFocus SlimJ electrodes; Sonova, Zürich, Switzerland), and Oticon (Neuro Zti EVO; Oticon A/S, Smørum, Denmark) between 2020 and 2023.

**Intervention:** Preoperative MRI images were utilized to measure the volume of the modiolus (VM), the cross-sectional areas of the CN (ACN), and for normalization, the area of the facial nerve (AFN) and the area of the internal ear canal (AIEC). Postoperative speech perceptions were assessed through word recognition scores (WRS) at several stages following the first fitting (FF) of the CI processor: immediately after FF, 1 month, 3 months, and 6 months after FF.

**Main Outcome Measures:** Sixty-eight patients were enrolled in this study. A statistically significant positive correlation between the ratio between ACN and AFN (ACN/AFN) and WRS<sub>FF</sub> was identified ( $R = 0.36$ ,  $p < 0.003$ ). However, this correlation disappeared in subsequent follow-up tests. Moreover, upon grouping patients based on their degree of asymmetrical hearing loss, it was observed that the correlation was primarily driven by patients with moderate to severe asymmetrical hearing loss (AHL<sub>m</sub>) on the contralateral side ( $R = 0.62$ ,  $p = 0.0003$ ).

**Conclusion:** The present results suggest that assessing the size of the CN through MRI has limited predictive utility for postoperative speech perceptions during CI consultations. This limitation seems to be particularly relevant for AHL<sub>m</sub> patients and is confined to the initial activation period.

**Key words:** Cochlear implant—Cochlear nerve—Magnetic resonance imaging (MRI)—Speech perception.

*Otol Neurotol* 00:00–00, 2024.

## INTRODUCTION

The cochlear implant (CI) electrically stimulates spiral ganglion neurons (SGN) and generates nerve impulse, which are then transmitted through the vestibulocochlear nerve to the auditory brainstem. Clinically, CI has been successfully implanted in a very broad patient spectrum ranging from infants to elderly, who exhibit severe-to-profound sensorineural hearing loss (SNHL) (1,2). In general, postoperative speech perception is highly promising and satisfying. However, there are often significant individual variabilities among patients (1). Previous studies have identified various demographic

factors that affect the outcome of CIs, including the age at implantation, history of hearing aid use, cognitive ability, parental socioeconomic status, language training, and the status of cochlear nerve (CN) (1,3–6). Among these factors, the integrity of the CN is particularly crucial (5,6). Thus, the accurate preoperative evaluation of the degree of CN impairment could potentially facilitate appropriate counseling regarding the outcomes of cochlear implantation.

The promontory stimulation test (PST) assesses the integrity of the CN by inserting a needle electrode through the tympanic membrane into the cochlear vicinity. However, this method is invasive, and its significance has been questioned due to the fact that negative results do not necessarily rule out the function use of a CI (7–10). In contrast, the ear canal stimulation test (ECST) offers a noninvasive alternative. It utilizes a silver ball ear canal electrode positioned close to the tympanic membrane. However, this method typically requires higher electric stimulation intensity to elicit auditory sensation, potentially leading to a higher incidence of

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Conflict of interest: The authors declare no competing interest.

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DOI: 10.1097/MAO.0000000000004293

unwanted somatosensory sensation (10–14). In contrast to these physiological tests, the most commonly employed non-invasive methods for preoperative assessment of the status of the CN involve a combination of computed tomography (CT) and magnetic resonance imaging (MRI). By analyzing CT and MRI images, CN deficiency (CND), encompassing CN hypoplasia and aplasia, can be detected. According to existing literature, CN hypoplasia is characterized by bony cochlear nerve canal (BCNC) diameter of  $<1.5$  mm and an internal auditory canal of  $<2$  mm (15,16). Aplasia, on the other hand, is determined when the CN is not observable in MRI (17,18). Regarding the postoperative benefits of CIs, several studies have demonstrated that patients with aplastic CNs tend to exhibit poorer outcomes compared to those with hypoplastic CNs after CI implantations (19,20). Besides, comparative studies have shown that the benefits of CIs in patients with CND were inferior to those in other children with SNHL who possessed normal-sized CNs (21,22). In 2015, Yamazaki et al. analyzed the correlation between the preoperative relative diameter of the vestibulocochlear nerve in the CPA as observed on the preoperative MRI scans, and the postoperative auditory performance with CI in congenitally deaf children with CND (23). Their findings revealed a statistically significant positive correlation (23). Collectively, these pieces of evidence suggest that the size of the CN serves as a potential biomarker for congenital hearing loss in these patients. However, a question arises regarding the results in adults with postlingual deafness. Given that most of these adult patients should have a normally developed size of CN at birth, further investigation is needed to understand how this factor may influence outcomes in this specific population. As directly presented in the human anatomical study, the diameter of the CN is smaller in patients with profound deafness throughout their lives compared to those with normal hearing (24).

This study aimed to measure the diameters of the CNs in adult patients with postlingual deafness and to investigate the correlation between these diameters and postoperative speech perception following CI surgery.

## MATERIALS AND METHODS

The local ethics committee approved this retrospective study (A 2023-0022). All patient data were anonymized and deidentified prior to the retrospective analysis.

### Subjects

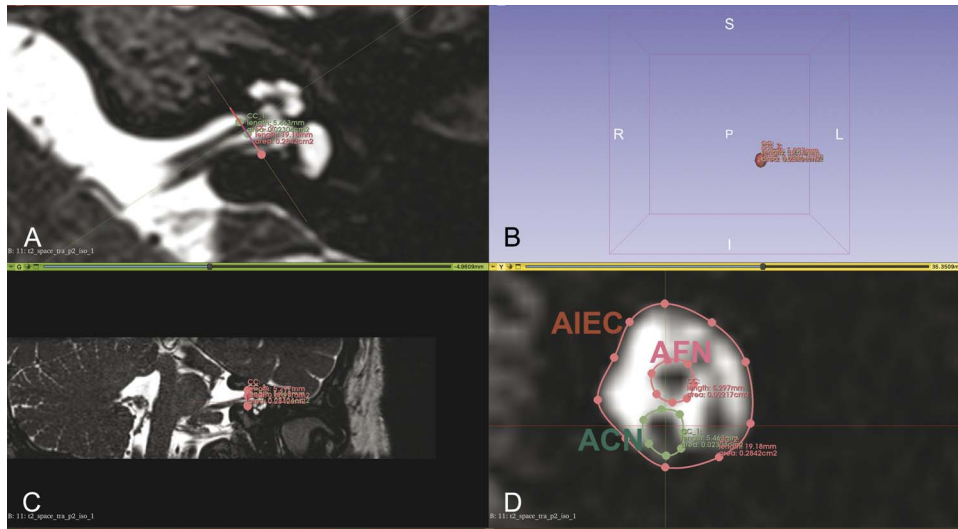
All patients who underwent a CI including MED-EL (Synchrony 2, FLEX electrode series; MED-EL, Innsbruck, Austria), Cochlear (slim straight electrodes; Cochlear Ltd., Sydney, Australia), Advanced Bionics (HiRes Ultra 3D CI, HiFocus SlimJ electrodes; Sonova, Zürich, Switzerland), and Oticon (Neuro Zti EVO; Oticon A/S, Smørum, Denmark) between 2020 and 2023 were retrospectively included in this study. Exclusion criteria comprised congenital deafness, cochlear malformation, patients with vestibular schwannoma, labyrinthitis, trauma, incomplete insertion of CI array (none), and noninformative speech tests due to patient age or language origin, as well as missing or inadequate preoperative

MRI examinations, missing high-resolution T2-weighted 3D sequences. Patient selection based on these criteria was conducted retrospectively utilizing operation reports, physician letters, processor fitting records, and in-clinic progress documents.

### MRT Protocol and Measurement of the CN

Each patient received a dedicated MRI examination before the CI surgery based on the guidelines (ZITAT S2k-LL CI-Implantation). MRI was acquired from different clinical MRI systems (1.5 or 3.0 T), with slight adjustments to the protocols depending on the department and individual MRI scanner on which the studies were done (1.5 T Avanto fit, 3.0 Skyra fit, or 3.0 T Vida MRI; Siemens Healthineers, Erlangen, Germany; 1.5 T Signa Artist or 3.0 T Signa Premier MRI; General Electric, California, USA). Assignment of patients to different MRI scanners was determined by appointment capacities. All dedicated protocols included pre- and postcontrast 3D T1-weighted sequences, as well as axial FLAIR and DWI whole brain, and heavily T2-weighted 3D sequences of the internal ear canal (IEC) and inner ear. Three-dimensional T2-weighted sequences with isotropic voxel size of less than 1 mm were obtained in all cases. Mainly, Fast (Turbo) spin echo sequences, optimized for isotropic 3D imaging, were used. For the 3.0 T Siemens scanners, the so-called sampling perfection with application optimized contrasts using different flip angle evolution (SPACE-) sequences with 0.5-mm voxel size was chosen. For the GE scanners, the respective 3D Fast spin echo sequence technique (CUBE) with 0.6-mm voxel size at the 1.5 T Signa Artist MRI and 0.4-mm voxel size at the 3.0 T Signa Premier scanner were used. Only at the Siemens 1.5 T Avanto fit MRI, a gradient echo sequence was used, i.e., 3D constructive interference in steady state (CISS) with 0.6-mm voxel size. The 3D T2-weighted sequences were exported from the PACS in DICOM format for the following measurements.

Measurements of the CN were obtained on the software 3D Slicer (www.slicer.org, Federov et al., 2012)(25). The DICOM files of the MRI pictures were transferred to the software. Based on axial pictures of the IEC, a plane perpendicular to the long axle of IEC was placed to build the parasagittal image. By moving the plane slowly from the cochlea to the CPA, the sectional image of the nerve in the IEC will be clearly displayed. Among all the sectional images, there is at least one section, at which all four nerves, CN, facial nerve (FN), vestibular nerve superior, and vestibular nerve inferior, are clearly demarcated. If multiple sections contain the four aforementioned structures, the analysis will focus on the first encountered section. Based on the section, the boundary lines of the CN and FN was outlined for the measurement of the area (Fig. 1). In order to measure the volume of the modiolus (VM), the axial images of the cochlea were analyzed. The boundary line of the modiolus was clearly demarcated slice by slice. Then the volume was automatically calculated by 3D Slicer. All the measurements were conducted by one ENT resident. Subsequently, each measurement was reviewed by one ENT senior consultant and one senior neuroradiologist. In cases where there was disagreement regarding the measurements, all three



**FIG. 1.** Screenshot of 3D Slicer showing the measurement of the areas of the CN (ACN), facial nerve (AFN), and inner ear canal (AIEC) from the parasagittal section.

individuals would convene for discussion and repeat the measurement process.

### Audiological Parameters

All participants underwent audiometric tests before CI surgery in both ears by skilled staff using a calibrated clinical audiometer (AT900; Auritec GmbH, Hamburg, Germany). Pure tones were presented at frequencies of 0.125, 0.25, 0.5, 0.75, 1, 2, 3, 4, 6, and 8 kHz through a headphone (DT48; Beyer, Heilbronn, Germany).

After CI surgery, speech recognition was evaluated by measuring the word recognition score (WRS) at 65 dB in a quiet environment at various stages after the initial fitting of the CI processor: initial fitting (FF), and 1, 3, and 6 months. The speech-test signal (Freiburg monosyllable test) was presented frontally in a soundproof room (1 × 2 × 44 m).

### Statistical Analysis

The investigation of the CN encompassed four metrics: the VM, the area of the CN (ACN), the area of the CN normalized to the area of FN (ACN/AFN), and the area of the CN normalized to the area of IEC (ACN/AIEC). Subsequently, these metrics underwent examination for

relationships with physiological and audiological variables. The physiological variables included in the analysis are sex, ear side, contralateral ear, and age. The audiological variables considered are preoperative hearing loss of the affected ear, asymmetrical hearing loss, and postoperative speech intelligibility throughout the follow-up care period. Differences in sex, ear side, and the contralateral ear were analyzed using a *t* test. Correlations with age, preoperative hearing loss, and postoperative speech intelligibility were examined using Pearson correlation. Differences in asymmetrical hearing loss were analyzed using a one-way ANOVA, followed by post hoc analysis using the Tukey test. The correlations between the CN size and speech recognition post-cochlear implant (CI) surgery at various stages—first fitting (FF), and 1, 3, as well as 6 months after FF—were examined.

## RESULTS

Sixty-eight patients were included in the study, comprising 25 males and 43 females. The mean age of the participants was 63.0 years, ranging from 22.7 to 89.8 years. Among them, 10 bilateral implanted subjects had both ears included, resulting in a total of 38 left ears and 40 right ears. The demographic data were presented in Table 1.

**TABLE 1.** Demographic table for participants

Group		SSD	AHLm	AHLh	Overall
Patient numbers		16	32	20	68
Age		52.7 ± 16.3	65.0 ± 15.9	68.0 ± 13.4	63.0 ± 16.3
Sex	M	4	15	6	25
	F	12	17	14	43
Company	MED-EL	9	26	17	52
	Cochlear	6	8	9	23
	Advanced Bionics	1	0	0	1
	Oticon	0	2	0	2
Bilateral CI		0 (0%)	4 (12.5%)	6 (30%)	10 (14.7%)

CI indicates cochlear implant; SSD, single-sided deafness; AHLm, moderate asymmetric hearing loss; AHLh, high asymmetric hearing loss.

All ears underwent CI surgery and had an average 4FPTA of  $98.2 \pm 17.9$  dB HL (mean  $\pm$  standard deviation). The contralateral ear exhibited an average 4FPTA of  $58.3 \pm 27.5$  dB HL. Sixteen patients were categorized as having single-sided deafness (SSD: the contralateral ear had an average 4FPTA  $\leq 30$  dB HL), 32 had moderate asymmetric hearing loss (AHLm: the contralateral ear had an average 4FPTA  $> 30$  dB HL and  $\leq 80$  dB HL), and 20 were classified as high asymmetric hearing loss (AHLh: the contralateral ear had an average 4FPTA  $> 80$  dB HL).

### Modiolus and CN

The mean VM measured  $4.35 \pm 0.62$  mm<sup>3</sup>, while the average ACN was  $0.0178 \pm 0.0057$  cm<sup>2</sup>. Similarly, the average AFN was  $0.0174 \pm 0.0051$  cm<sup>2</sup>, and the average AIEC was  $0.23 \pm 0.063$  cm<sup>2</sup>. Notably, the CN's area represented approximately 7.6% of the IEC.

The investigation of the CN involved four metrics: the VM, the ACN, the ACN/AFN, and the ACN/AIEC. Following this, these metrics underwent analyses for correlations with physiological and audiological variables (Table 2). No age-related effects or influence from preoperative hearing loss on nerve size parameters were identified in the Pearson correlation. Moreover, no impact was observed on these parameters based on sex and ear side from the *t* test. Similarly, no relationship was found between asymmetric hearing loss in the ANOVA. Furthermore, no significant differences in the parameters were observed when comparing the cochlear implant ear with its corresponding contralateral ear (Fig. 2).

### CN and Speech Recognition

Pearson correlations were conducted between word recognition scores (WRS) and the VM, the ACN, the ACN/AFN, and the ACN/AIEC (Table 3). Only one significant correlation emerged between WRS<sub>FF</sub> and ACN/AFN ( $R = 0.36$ ,  $p = 0.003$ ). At all other time points, no clear correlation was identified between the CN and WRS. Moreover, no significant correlation was identified between VM, ACN, ACN/AIEC, and WRS.

$$\text{WRS}_{\text{FF}} = 67.2 \cdot \frac{\text{ACN}}{\text{AFN}} - 34.2 \quad (1)$$

Subsequently, the relationship between ACN/AFN and WRS<sub>FF</sub> in the aforementioned subgroup was separately examined. This correlation analysis revealed that only the AHLm group exhibited a significant correlation with WRS<sub>FF</sub> ( $R = 0.62$ ,  $p = 0.0003$ ) (Fig. 3). The relationship between WRS<sub>FF</sub> and ACN/AFN can be expressed as a linear model for prediction, as indicated in Eq. (1). The predictive accuracy of this model was estimated at  $16.1 \pm 10.8\%$ .

### DISCUSSION

#### MRI Did Not Detect CN Size Change in Patients With Postlingual Deafness

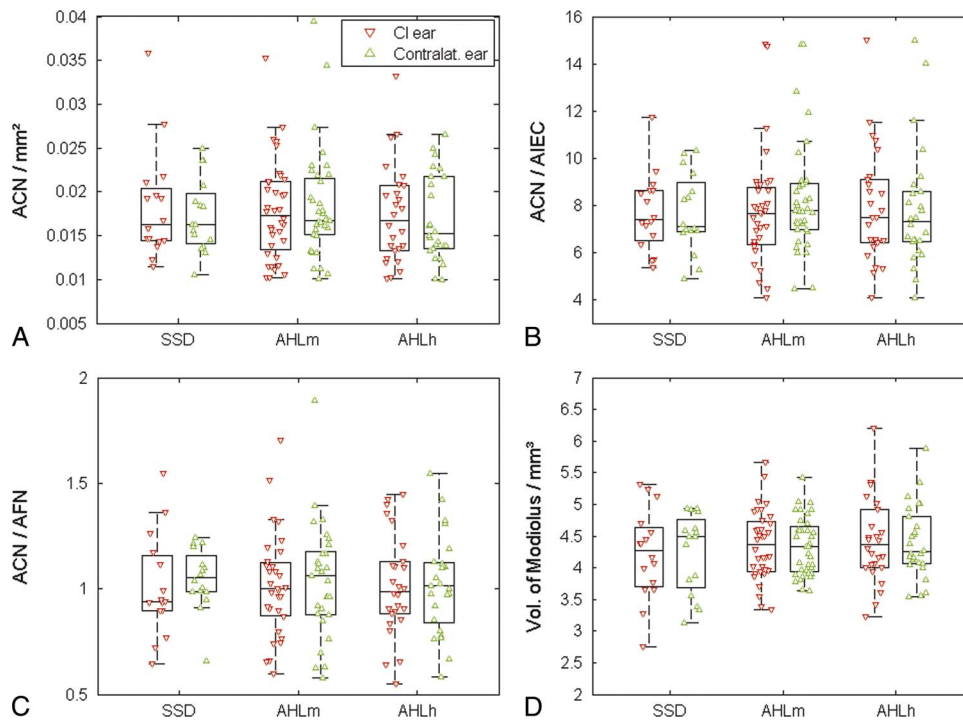
Deafness is reported to lead to changes in the CN, specifically reduce the number of spiral ganglion cells (26). The counts of the remaining spiral ganglion cell have been reported to correlate significantly with the maximum diameter

**TABLE 2.** Statistical analysis of the relationship between physiological and audiological factors and CN metric

Physiological /Audiological Variable		CN Metric	Statistical Test	Statistical Measure	<i>p</i>
Age		VM	Pearson correlation	$R = -0.01$	0.87
		ACN		$R = -0.04$	0.64
		ACN/AFN		$R = -0.08$	0.41
		ACN/AIEC		$R = -0.10$	0.24
Sex		VM	<i>t</i> test	$T = 1.20$	0.23
		ACN		$T = 0.05$	0.95
		ACN/AFN		$T = 1.01$	0.31
		ACN/AIEC		$T = 0.03$	0.98
Asymmetric hearing loss		VM	ANOVA	$F = 0.60$	0.55
		ACN		$F = 0.11$	0.90
		ACN/AFN		$F = 0.21$	0.81
		ACN/AIEC		$F = 0.05$	0.95
Contralateral ear (SSD)	VM	VM	<i>t</i> test	$T = 0.01$	0.99
	ACN	ACN		$T = 0.16$	0.88
	ACN/AFN	ACN/AFN		$T = 1.20$	0.24
	ACN/AIEC	ACN/AIEC		$T = 0.06$	0.78
Contralateral ear (AHLm)	VM	VM	<i>t</i> test	$T = 0.53$	0.60
	ACN	ACN		$T = 0.34$	0.73
	ACN/AFN	ACN/AFN		$T = 0.94$	0.35
	ACN/AIEC	ACN/AIEC		$T = 0.28$	0.78
Contralateral ear (AHLh)	VM	VM	<i>t</i> test	$T = 0.52$	0.60
	ACN	ACN		$T = 0.91$	0.37
	ACN/AFN	ACN/AFN		$T = 1.03$	0.31
	ACN/AIEC	ACN/AIEC		$T = 0.36$	0.72

CN indicates cochlear nerve; VM, volume of the modiolus; ACN, area of the cochlear nerve; ACN/AFN, area of the cochlear nerve normalized to the area of the facial nerve; ACN/AIEC, area of the cochlear nerve normalized to the inner ear canal area; SSD, single-sided deafness; AHLm, moderate asymmetric hearing loss; AHLh, high asymmetric hearing loss.





**FIG. 2.** Comparison of the CN between the ear with cochlear implant (CI) and the contralateral ear across the four groups with different degrees of asymmetrical hearing loss.

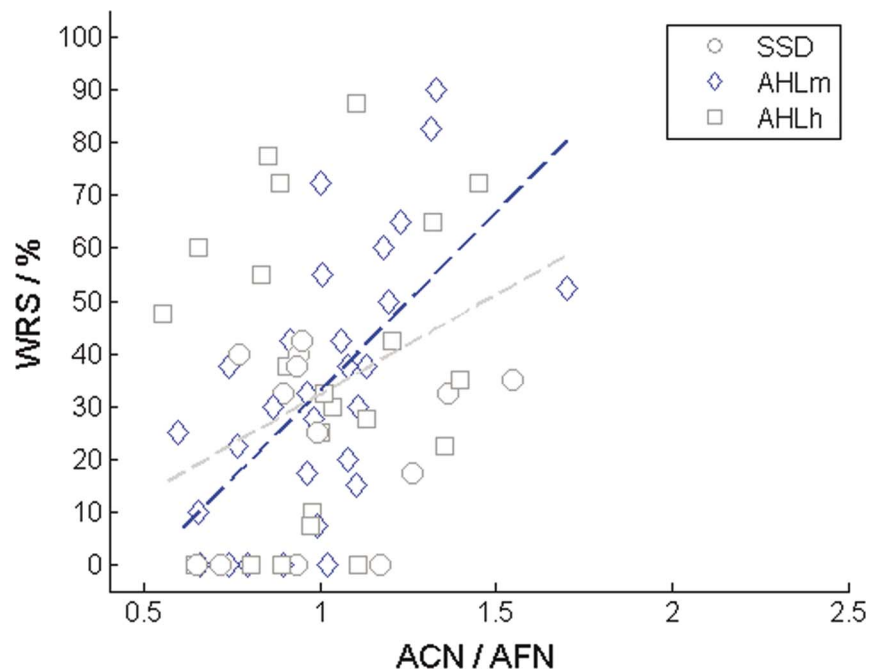
of the cochlear and eighth cranial nerve (27). Another study on human temporal bones has directly measured the maximum diameter of the AN in deaf patients and found that the diameter is significantly smaller than in normal hearing population (24). However, conducting histological studies in living human beings is not feasible. This raises the question whether advanced radiological techniques can detect subtle changes in the AN in the human population. In the early stages, some researchers measured the length and width

of the bony CN canal using high-resolution temporal bone computed tomography (HRCT) and found them to be significantly smaller in ears with congenital hearing loss (28,29). In comparison, current MRI can directly visualize the CN, providing a more precise and accurate assessment (26,30). Despite attempts to analyze CN size with MRI in patients with hearing loss, the results are inconclusive. Russo et al. (31) reported mild hypoplasia in the CN in children with sensorineural hearing loss. Sildiroglu et al. (30) found no

**TABLE 3.** Statistical analysis of the relationship between CN metric and WRS in different groups at different time points after activation of CI

WRS at Time Point	CN metric	Pearson Correlation				<i>p</i>			
		SSD	AHLm	AHLh	Total	SSD	AHLm	AHLh	Total
First fitting	VM	0.15	-0.06	0.07	0.04	0.60	0.74	0.76	0.73
	ACN	0.22	0.03	0.10	0.09	0.44	0.87	0.67	0.47
	ACN/AFN	0.24	<b>0.62**</b>	0.14	<b>0.36*</b>	0.44	<b>0.0003</b>	0.533	<b>0.003</b>
	ACN/AIEC	-0.05	0.04	0.18	0.07	0.86	0.84	0.43	0.58
1 mo	VM	-0.33	-0.08	0.29	0.04	0.26	0.65	0.16	0.72
	ACN	0.22	-0.07	0.15	0.07	0.48	0.70	0.48	0.58
	ACN/AFN	-0.3	0.34	0.03	0.08	0.34	0.08	0.89	0.70
	ACN/AIEC	-0.03	-0.04	0.08	0.01	0.91	0.81	0.72	0.91
3 mo	VM	-0.21	-0.09	0.35	0.04	0.46	0.62	0.15	0.76
	ACN	0.07	-0.21	0	-0.08	0.82	0.27	0.98	0.56
	ACN/AFN	-0.43	0.11	0.29	0.05	0.14	0.60	0.24	0.70
	ACN/AIEC	-0.24	-0.15	0.13	-0.06	0.41	0.44	0.59	0.66
6 mo	VM	-0.02	0.13	0.25	0.14	0.95	0.56	0.35	0.31
	ACN	0.18	-0.09	-0.01	0.01	0.57	0.66	0.96	0.95
	ACN/AFN	-0.05	0.30	0.11	0.14	0.88	0.20	0.70	0.36
	ACN/AIEC	-0.05	-0.29	0.08	-0.10	0.89	0.17	0.76	0.48

CI indicates cochlear implant; CN, cochlear nerve; WRS, word recognition scores; VM, volume of the modiolus; ACN, area of the cochlear nerve; ACN/AFN, area of the cochlear nerve normalized to the area of the facial nerve; ACN/AIEC, area of the cochlear nerve normalized to the inner ear canal area; SSD, single-sided deafness; AHLm, moderate asymmetric hearing loss; AHLh, high asymmetric hearing loss.



**FIG. 3.** Area of the CN normalized to the area of the facial nerve (ACN/AFN) and the word recognition score after the initial fitting for four groups with different degrees of asymmetrical hearing loss: single-sided deaf (gray circles), moderate asymmetric hearing loss (dark blue diamonds), and high asymmetrical hearing loss (gray squares). The Pearson correlation analyses showing a positive correlation with  $R = 0.36$  in the whole group (gray dotted line) and an enhanced correlation with  $R = 0.62$  in the subgroup of AHLm (dark blue dotted line).

significant change in CN size on MRI in patients with sensorineural hearing loss. Kim et al. (26) discovered a negative correlation between CN size and both the duration of deafness and the degree of hearing loss.

In this study, the cross-section of the CN on both sides of the same patient was measured and compared to the CN size on CI side to the contralateral one. Additionally, patients were classified into three different groups based on the degree of hearing loss on the contralateral side. The results revealed no significant differences between the two sides, considering both the absolute values and various normalized measurements, across all three groups. Therefore, it can be presumed that deviations in CN diameter are lost in the noise of the natural variation of the CN or the MRI may not be sensitive enough to detect subtle changes in the CN following postlingual deafness. One limitation of our study is the absence of clear reconstruction of the duration of deafness. It is well established that the degeneration process of the CN system takes years. To observe morphological changes in the CN through MRI, a significant amount of time may be required. This may also explain why differences in the subgroup with single-side deafness (SSD) could not be observed. In the SSD subgroup, all patients suffered a sudden hearing loss and most underwent CI surgery approximately 6 months after the onset of deafness.

### MRT Predicts Postoperative Speech Perception in CI Patients at the First Fitting Process

It is well known that the CN status directly affects the postoperative speech perception. In this study, a positive correlation between CN size and postoperative speech perception in CI patients at the first fitting process was found.

Similar findings were also reported by Kim et al. (26). However, in their study, a weaker correlation was identified, possibly attributed to the lack of a precise definition of the exact time when the postoperative speech tests were conducted. In this study, it was also noted that this correlation diminished during the follow-up period. Therefore, if speech tests were administered a few weeks after CI activation, this observation might have been overlooked.

The second point that should be discussed is that the correlation was only evident in the subgroup of AHLm and not in the other groups. This may be explained by the following factors 1) In the SSD group, despite using masking noise for the normal hearing ear during the speech test of the CI ear, the normal ear may still pick up the signal sounds in the free field speech test. This suggests a potential issue with the accuracy of the speech test results for the CI ears in SSD users. 2) In the AHLh group, challenges were encountered often during the fitting process. Patients faced difficulties in performing the task, particularly due to communication difficulties during the fitting process. This issue arises because the CI processor has not been adjusted yet, and patients with AHLh also struggle with understanding speech through the contralateral ear. Therefore, it may be that the fitting process in these patients cannot always be accurately performed. Specifically, the threshold and comfortable levels might not be correctly defined, leading to suboptimal postoperative speech performance.

The main limitation of this study lies in its retrospective design. Consequently, the consistency of measurement conditions could not be maintained throughout the period under review. Factors such as variations in MRI image quality, differences

in adaptation strategies, and updates to manufacturers' processors contributed to variability in this data. Additionally, standard clinical diagnostics and care evolve over time, which could have affected the interpretation of results. These limitations could be addressed more effectively in a prospective study.

Finally, it is noteworthy that the correlation, observed in both the entire group and the AHLm subgroup, diminished in the subsequent follow-up tests. A plausible explanation for this phenomenon could be attributed to the inherent plasticity of the central nervous system (32,33). A typical example involves patients with short intracochlear electrode arrays. In these cases, their implants are programed to provide electrical stimulation based on acoustic signals, extending up to two octaves below the frequencies that would typically activate that cochlear region. Over the course of several years of device usage, the patients' perceptions of electrode pitch align with the programed frequencies, deviating from those predicted based on cochlear position (34). Additionally, numerous researchers have documented that postlingually deaf implant patients exhibit normal pitch perceptions (35–37).

## CONCLUSION

In conclusion, the findings of this study indicate that measuring the CN size from MRI has limited predictive value for postoperative speech perceptions during CI consultations. This limitation appears to be applicable specifically to patients with moderate hearing loss on the contralateral side and only for the time of activation.

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